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**EVALUATING 1 AND 2D DIMENSIONAL MODELS FOR FLOODPLAIN
INUNDATION MAPPING**

by

M.G. ANDERSON AND P.D. BATES

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Professor M.G. Anderson

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In this report the development of a new model for simulating flood inundation is briefly outlined (see table 1). The model is designed to operate with high resolution raster Digital Elevation Models which are becoming increasingly available for many lowland floodplain rivers and is based on what we hypothesise to be the simplest possible process representation capable of simulating dynamic flood inundation. This consists of a one-dimensional kinematic wave approximation for channel flow solved using an explicit finite difference scheme and a two-dimensional diffusion wave representation of floodplain flow. The model is applied to a 35 km reach River Meuse in the Netherlands using only published data sources (see Table 2) and used to simulate a large flood event which occurred in January 1995. This event was chosen as air photo and Synthetic Aperture Radar (SAR) data for flood inundation extent are available to enable rigorous validation of the developed model (see Figure 1). 100, 50 and 25 m resolution models were constructed and compared to two other inundation prediction techniques: a planar approximation to the free surface and a relatively coarse resolution two-dimensional finite element scheme. The model developed in this paper out-performs both the simpler and more complex process representations, with the best fit simulation correctly predicting 81.9 % of inundated and non-inundated areas. This compares to 69.5 % for the best fit planar surface and 63.8 % for the best fit finite element code. However, when applied solely to the 7 km of river below the upstream gauging station at Borgharen the planar model performs almost as well (83.7 % correct) as the raster model (85.5 % correct). This is due to the proximity of the gauge which acts as a control point for construction of the planar surface and the fact that here low lying areas of the floodplain are hydraulically connected to the channel. Importantly though it is impossible to generalise such application rules and thus we cannot specify *a priori* where the planar approximation will work. Simulations also indicate that, for this event at least, dynamic effects are relatively unimportant for prediction of peak inundation. Lastly, consideration of errors in typically available gauging station and inundation extent data shows the raster based model to be close to the current prediction limit for this class of problem.

Figure 1. Time series of inundation extent predicted by a dynamic simulation of the raster model using a 25 m resolution DEM for the 7 km reach downstream of the Borgharen gauging station. This is compared to the air photo derived shoreline sampled at approximately 160 hours into the simulation.

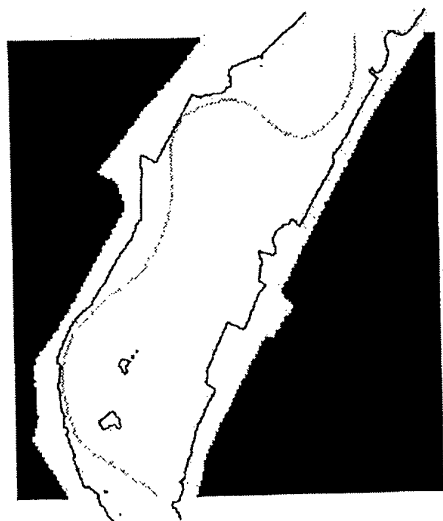
Type/name of model	Authors	Channel routing	Floodplain routing	Discretisation	Application/validation
Planar water surface	Priestnall <i>et al.</i> (in press)	None.	None.	Planar surface is overlain onto either raster or TIN based Digital Elevation Models. All areas below the planar surface are considered flooded.	Applied to DEM's generated by the UK Environment Agencies LIDAR data collection programme (REF). No validation data was presented.
Storage Cell	Cunge <i>et al.</i> (1976) and Romanowicz <i>et al.</i> (1996).	Uniform flow formulae (Manning and weir-type equations) using designated channel cells (option c above).	Uniform flow formulae (Manning and weir-type equations).	Valley is split into channel and single cells representing the left and right floodplains.	Applied by Romanowicz <i>et al.</i> to an 11 km reach of the river Culm, UK using 285 cells. Validated against output from 2D FE scheme rather than field data.
Storage cell	Estrela (1994).	Uniform flow formulae (Manning and weir-type equations) using designated channel cells (option c above).	Uniform flow formulae (Manning and weir-type equations).	Polygonal cells used for the floodplain, interlinked by channels. Cells follow existing natural boundaries and hence requires the user to discretized the floodplain. Several cells can be used in each floodplain cross section.	Applied to 250 km ² of the River Júcar floodplain, Spain using 403 cells. A 50 year recurrence interval flood was simulated and calibrated against an unspecified number of water depth observations. No validation data was presented.
Storage (FLOODSIM) cell	Bechteler <i>et al.</i> (1994).	One-dimensional model (no details given) running between floodplain cells (option b above).	Uniform flow formulae (weir-type equations).	Triangular Irregular Network (TIN) with channels placed on the cell faces	Applied to a 4 x 2.5 km reach of the River Rhine near Iffezheim and 2 x 0.6 km reach of a river valley near Coburg. Simulations used up to 33 000 cells with a minimum resolution of 5 m. No validation data was presented.
Storage (LISFLOOD-FP) cell	Bates and de Roo (this paper).	One-dimensional kinematic wave solved using an explicit finite difference procedure using designated channel cells (option c above).	Uniform flow formulae (Manning equation).	Raster-based discretization derived automatically from a DEM.	Applied to a major flood on a 35 km reach of the River Meuse using various resolution DEM's and up to 37 000 cells. Validated against high resolution air-photo and satellite derived inundation extent data and gauging station records (see Section Error! Reference source not found.).
1D models (MIKE11, ISIS, ONDA, HEC-RAS, FLUCOMP among others)	Fread (1984), Ervine and Macleod (1999)	Full solution of the 1D St. Venant equations.	Full solution of the 1D St. Venant equations.	Treats domain as a series of cross section perpendicular to the flow direction. Areas between cross section are not explicitly represented.	Typical application described by Penning-Rowse and Tunstall (1996). Here the ONDA code was applied to circa 20 km of the lower River Thames, UK using 1000 cross section to define the channel/floodplain geometry. Validation has typically been undertaken against gauged records and, more infrequently, inundation extent.
2D Models (RMA-2, TELEMAC-2D, MIKE21, among others).	Feldhaus <i>et al.</i> (1992), Bates <i>et al.</i> (1992), Bates <i>et al.</i> (1995).	Full solution of the 2D St. Venant equations with turbulence closure.	Full solution of the 2D St. Venant equations with turbulence closure.	Structured grids (finite difference methods) or unstructured grids (finite volume and finite element methods) using a variety of geometries, but typically triangles or quadrilaterals.	Typical applications presented by Bates <i>et al.</i> (1998) for five river reaches between 0.5 and 60 km in length and using up to 15000 triangular finite elements. Validated against dynamic water levels internal to the model domain and low resolution satellite imagery of flood inundation extent (Bates <i>et al.</i> , 1997).

Table 1: Comparison of previous storage cell approaches to modelling flood inundation and standard hydraulic models to the new approach presented in this paper. Model complexity increases down table.

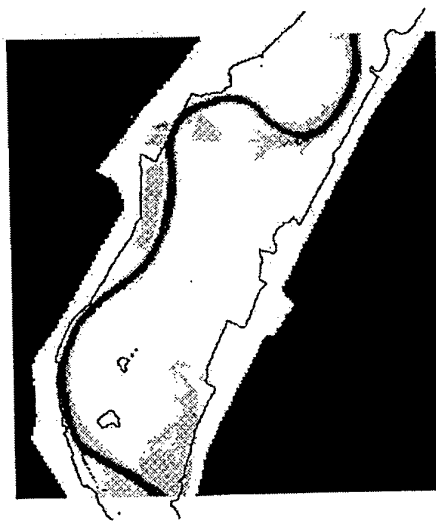
Data requirement	Source	Comments
Raster Digital Elevation Model.	Typically derived from air photogrammetry or airborne laser altimetry (LiDAR).	Grid resolutions of approximately 25-100m would seem appropriate for most floodplain applications, although smaller resolution are obviously preferable. Vertical accuracy of the DEM should generally be less than ± 0.25 m.
Inflow discharge hydrograph.	Gauging station records. Flow enters the model through the upstream channel cell forming the first location on the local drainage direction map.	Model can be used in either steady state or dynamic modes, but flows should be accurate to ± 10 %. For dynamic simulations, temporal resolution depends on the speed of the hydrograph rise but typically at least hourly data are required.
Channel slope.	Taken from the DEM or surveyed cross sections.	Can be set individually for each grid cell if necessary.
Channel width.	Taken from the DEM or surveyed cross sections.	Can be set individually for each grid cell if necessary. Need not be the same as the model grid resolution.
Bankfull depth.	Taken from the DEM or surveyed cross sections.	Can be set individually for each grid cell if necessary.
Initial estimate of channel flow depth	Reasonable value based on experience and examination of surveyed cross sections and rating curves.	Model is run with constant in-bank discharge for a start up period to allow realistic channel water depths and flow velocities to develop. Start up period should be based on the time taken for flood waves to cross the domain.
Channel and floodplain friction.	User defined parameters typically chosen with reference to published tables such as those given by Chow (1959) or Acrement and Schneider (1984).	N_c typically between 0.01 and 0.04 N_p typically between 0.03 and 0.15 Can be set individually for each grid cell if necessary.
Model time step	User defined based on Courant number stability constraints. An explicit numerical scheme is used so the stability is a function of the cell dimensions and the flow rate. As water enters the model via a single inflow cell at the head of the reach, flow rates in this cell are usually the limiting factor.	Varies between applications but typical values are in the range 2-20 s.

Table 2: Summary of model data and parameter requirements.

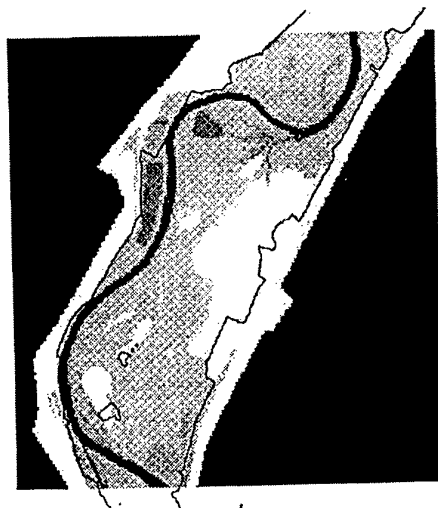
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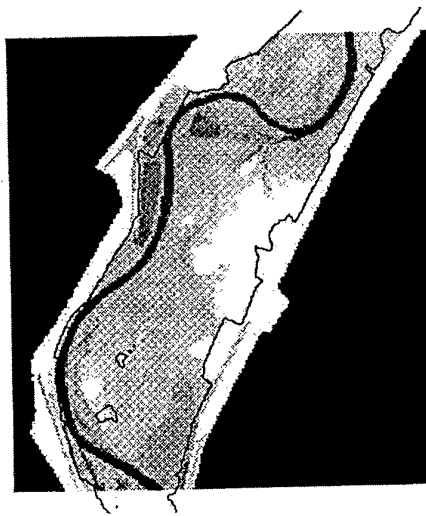
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167 hours



222 hours



333 hours

